NASA TECH BRIEF

Lewis Research Center

CARBIDE FACTOR PREDICTS ROLLING-ELEMENT BEARING FATIGUE LIFE

The Problem:

To determine the effect of the carbide constituent on the fatigue life of rolling-element bearings. Previous research has shown that rolling-element fatigue life decreases as the total amount of alloying elements such as molybdenum, chromium, vanadium, tungsten, and cobalt increased. Recent transition from AISI 52100 steel to the more highly alloyed tool steels (AISI M-1, M-2, M-10, M-42, M-50, T-1 and Halmo) has resulted in greater dimensional stability, retention of hot hardness, wear resistance, and oxidation resistance at high temperature, but fatigue life has lessened. Most of the alloying elements are strong carbide formers: it was felt that an interrelation might exist between the number and size of carbide particles and rolling-element fatigue life.

The Solution:

An analysis was made to determine if a correlation does exist between the number and size of carbide particles and rolling-element fatigue. Such correlation was established, and a carbide factor was derived that can be used to predict fatigue life more effectively than such variables as heat treatment, chemical composition and hardening mechanism.

How It's Done:

The materials analyzed were consummable-electrode, vacuum-melted (CVM) AISI 52100, AISI-M-1, M-2, M-10, M-42, M-50, AISI T-1, and Halmo. Groups of 12.7 mm (½ inch) diameter balls of each material were first tested in a five-ball fatigue tester, at a maximum Hertz stress of 5.52 x 10^9 newtons per square meter (800,000 psi), a contact angle of 30°, and a shaft speed of 10,300 rpm to determine the fatigue life. Tests were run at a race temperature of 340 K (150°F) with a super-refined naphthenic mineral oil as the lubricant. For each of the eight materials, three lots were tested. Each test group of five balls was taken from a single lot. From 25 to 30 five-ball tests were run for each material lot. Each test run was terminated when either an upper-test ball or a lower-test ball failed, or at 100 hours. The test results of the three lots of each material were combined, and a Weibull analysis was performed on the combined results to determine the 10-percent fatigue life of each of the materials.

From each material lot, one test ball was chosen at random, mounted, metallographically polished, and etched. Each ball was then examined on a Quantimet Image Analyzing Computer (QTM) to determine the total number of carbide particles in a unit area, particle size, and percent carbide area in a unit area.

Essentially, the QTM projects a microscope image on a vidicon tube and scans it electronically. Differences in optical density are detected, recorded, and processed to read out the size of the discriminated (carbide particle) area in percent of the measured surface, the number of particles in the field of view, and the mean and median sizes of the particles.

Five areas were examined on each sample ball. Four areas were near the surface and 90° apart; the fifth area was near the center of the ball. The values obtained were averaged to obtain what was considered the average value of the variables for each of the eight materials tested.

From the test data and a statistical analysis, a carbide factor, C, was derived that was capable of predicting the rolling-element fatigue lives of the materials investigated within an acceptable variance. The carbide factor is determined from the following formula:

$$C = \frac{3}{\frac{M}{0.26} + \frac{718}{n} + \frac{a}{9.54} + 4\,Co}$$

where a = percent area of carbides

M = median carbide particle size (length)

n = total number of carbide particles per unit area

Co = weight percent cobalt

(continued overleaf)

The correlation coefficient for the prediction of the rolling-element fatigue lives for the materials tested was between 83 and 87%.

Notes:

1. The carbide parameter may also be applicable to predicting other types of fatigue (i.e., bending, rotating-bending, etc.).
2. The following documentation may be obtained from:
   National Technical Information Service
   Springfield, Virginia 22151
   Single document price $3.00
   (or microfiche $0.95)

   Reference: NASA TN-D-6835 (N72-26407), Effect of Carbide Size, Area, and Density on Rolling-Element Fatigue
3. Technical questions may be directed to:
   Technology Utilization Officer
   Lewis Research Center
   21000 Brookpark Road
   Cleveland, Ohio 44135
   Reference: B73-10008

Patent Status:

NASA has decided not to apply for a patent.

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